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Evaluation of Airborne Asbestos Concentrations Before and during an O and M (Operations and Maintenance) Activity: A Case Study

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EVALUATION OF AIRBORNE ASBESTOS CONCENTRATIONS BEFORE AND DURING AN O&M ACTIVITY: A Case Study

by

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16. ABSTRACT

The current lack of information regarding the impact of O&M activities on the potential for asbestos exposure to building staff and occupants prompted this study. This report presents a statistical evaluation of airborne asbestos data collected before and durig an O&M activity involving removal of thermal surface insulation from a feedwater preheater tank in a boiler room. It also presents a comparison of transmission electron microscopy (TEM) analysis on 0.4 -um-pore-size polycarbonate and TEM analysis on 0.8-um-pore-size mixed cellulose ester membrane filters. Containment barriers should be designed and maintained for effective prevention of significant increases in airborne asbestos concentrations in the areas adjacent to an O&M activity.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report provides information on the nature and controllability of releases of toxic substances to air from product uses, specifically asbestos-containing materials used as thermal insulation. It also provides an evaluation of airborne asbestos concentration data collected before and during an Operations and Maintenance (O&M) activity involving the removal of asbestos-containing material (ACM). These historical data are evaluated by standard statistical methods to determine if the O&M activity significantly increased the airborne asbestos concentration in the area.

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ABSTRACT

This report presents a statistical evaluation of airborne asbestos data collected before and during an operations and maintenance (O&M) activity involving the removal of thermal surface insulation from a feedwater preheater tank. Containment barriers should be designed and maintained for effective prevention of significant increases in airborne asbestos concentrations in the areas adjacent to an O&M activity.

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SECTION 1

INTRODUCTION

BACKGROUND

The U.S. Environmental Protection Agency (EPA) has issued guidance documents to assist building owners in developing an Operations and Maintenance (O&M) program to control exposure to asbestos when asbestos-containing material (ACM) is present in the building.[1,2,3] Asbestos-containing material includes surface material, thermal surface insulation, or other materials such as ceiling and floor tiles.[3] In theory, an O&M program should be designed and implemented to protect building staff and occupants from the release of asbestos fibers and to warn them of potential hazards created by the disturbance of ACM under uncontrolled conditions. The O&M program should continue as long as the ACM remains in the building.

The overall goal of an asbestos O&M program is to maintain the building environment free of asbestos contamination. The specific program objectives are 1) to remove asbestos fibers that may have been released from the ACM, and 2) to minimize future release and distribution of fibers by controlling activities that might disturb the ACM.

The O&M program focuses on the activities of custodial and maintenance workers and service contractors. Special procedures for routine cleaning by custodial workers are designed to achieve the first program objective, the collection of previously released asbestos fibers. Special work practices and procedures are designed for maintenance workers to achieve the second program objective, minimization of ACM disturbance. The work practices and procedures are tailored to three types of projects: 1) those that are unlikely to involve any contact with ACM; 2) those that may cause accidental disturbance of ACM; and 3) those that involve small-scale manipulation or removal of ACM. The O&M program also specifies emergency response actions for asbestos-fiber-release episodes.

The current lack of information regarding the impact of O&M activities on the potential for asbestos exposure to building staff and occupants prompted this study. This report presents a statistical evaluation of airborne asbestos data collected before and during an O&M activity involving removal of thermal surface insulation from a feedwater preheater tank in a boiler room. It also presents a comparison of transmission electron microscopy (TEM) analysis on 0.4-μm-pore-size polycarbonate and TEM analysis on 0.8-μm-pore-size mixed cellulose ester membrane filters.

OBJECTIVES

The following were the primary objectives of the study:

- To document a case study of one site on the effectiveness of work practices and procedures in preventing the release of asbestos fibers outside the work area during an O&M activity involving removal of thermal surface insulation.

- To determine if 0.4-µm-pore-size polycarbonate and 0.8-µm-pore-size mixed cellulose ester membrane filters produce equivalent estimates of airborne asbestos concentrations.

SECTION 2

CONCLUSIONS

The principal conclusions reached during this study of O&M procedures are as follows:

1) Inadequate sealing of a glove-bag type enclosure resulted in a statistically significant increase in airborne asbestos concentrations in the perimeter area during removal of the thermal surface insulation.

2) The TEM analysis of paired 0.8-µm-pore-size mixed cellulose ester and 0.4-µm-pore-size polycarbonate filters produced statistically equivalent estimates of airborne asbestos concentrations. (At the time of this study, EPA sampling guidance recommended the use of 0.8-µm-pore-size cellulose ester or 0.4-µm-pore-size polycarbonate filters to collect airborne asbestos fibers, whereas AHERA specifies the same filter type but a pore size of 0.45-µm for cellulose ester filters).

SECTION 3

RECOMMENDATIONS

This research study illustrates that O&M activities involving the removal of thermal system ACM may result in elevated asbestos fiber concentrations in adjacent areas of the building. Air monitoring should be considered a necessary element of an O&M activity that disturbs ACM in a building. Research is needed to develop or identify effective minicontainment systems for controlling the release of asbestos fibers into adjacent building areas.

SECTION 4

STUDY DESIGN AND METHODS

SITE DESCRIPTION

A single site was selected for conducting air monitoring before and during an O&M activity involving removal of asbestos-containing thermal surface insulation. The selected site, a boiler room of a commercial research laboratory, met the following criteria:

1. No abatement of ACM had occurred inside the building site within the preceding 6 months.

2. The asbestos was being abated as part of a scheduled maintenance operation.

3. The building owner agreed to cooperate with the EPA and to allow air monitoring to be performed during the maintenance activity.

The O&M activity involved removal of approximately 57 ft^2 of thermal surface insulation from a 6-ft-high feedwater preheater vessel with a base of 2.5 feet. The feedwater vessel was to be replaced as part of scheduled maintenance of boiler room equipment. The vessel was located on the operating platform on the second deck of the boiler room, which measured 75 ft x 150 ft x 20 ft. An abatement contractor was conducting the ACM removal.

O&M ACTIVITY

The glove-bag technique was used during removal of the thermal surface insulation. This containment method involved enclosing the vessel with one layer of 6-mil polyethylene plastic sheeting and splicing several sleeve and glove assemblies (standard glove bags) into the enclosure. The containment did not include a negative-pressure air filtration system.

Two workers wearing full protective clothing and powered air-purifying respirators removed the surface insulation. All work was performed from outside the enclosure by inserting their hands and arms through the built-in sleeves of the glove bags. Prior to the removal effort, an auxiliary sleeve was used to introduce a nozzle to wet the insulation with an amended water solution. During removal, asbestos-containing debris fell to the bottom of the bag. Some of the debris escaped through the seams in the bag and fell

approximately 7 feet to the uncovered floor of the boiler room. Analysis of this material showed that it contained approximately 42 percent chrysotile, 33 percent amosite, and 10 percent crocidolite.

Subsequent to the removal of the insulation, all substrate surfaces were wire-brushed and wet-wiped repeatedly to remove all residual material. The asbestos-containing debris and the plastic glove bags were then containerized in double 6-mil polyethylene bags and disposed of at an approved sanitary landfill.

SAMPLING STRATEGY

Table 1 presents an air-sampling matrix. Area air samples were collected before and during removal of the thermal surface insulation from the feedwater vessel. Both the before- and during-removal samples were collected in the perimeter area of the feedwater vessel. Outdoor area air samples also were collected before removal.

TABLE 1. AIR SAMPLING MATRIX

	Location and number of samples					
	Perimeter		Outdoors		Field blank	
Samples collected	PC[a]	MCE[b]	PC	MCE	PC	MCE
Before asbestos removal	10	10	5	5	1	1
During asbestos removal	9	8[c]	0	0	1	1
Total samples	19	18	5	5	2	2

[a] Polycarbonate filter.

[b] Mixed cellulose ester filter.

[c] A ninth sample could not be analyzed.

Two side-by-side air samples were collected at each sampling location. Each pair of samples consisted of a 25-mm, 0.4-μm-pore-size, polycarbonate (PC) filter and a 25-mm, 0-8-μm-pore-size, mixed cellulose ester (MCE) filter. When this study was designed and implemented, EPA recommended the use of 0.8-μm-pore-size mixed cellulose ester or 0.4-μm-pore-size polycarbonate membrane filters to collect airborne asbestos fibers;[2,4] however, current AHERA guidance specifies the same filter types, but a different pore size (0.45-μm) for the mixed cellulose ester filter.[5]

SAMPLING METHODS

Two side-by-side area air samples were collected at each sampling location. Each pair of samples consisted of a 25-mm, 0.4-µm-pore-size polycarbonate filter and a 25-mm, 0.8-µm-pore-size mixed, cellulose ester filter. Each 25-mm filter was mounted on a 5-µm-pore-size, mixed cellulose ester, backup diffusing filter and cellulose support pad and was contained in a three-piece cassette with a 50-mm conductive cowl and face cap. The base and cowl sections of the cassettes were sealed with vinyl adhesive tape to prevent air filtration through the seams of the cassettes during sampling. The filter cassettes were positioned 4 to 5 feet above the floor and arranged in a horizontal line by clipping them to a sturdy stand. The filter cassettes were placed approximately 5 cm apart and oriented in the same direction as the filter face, angled slightly downward. During sampling, the face cap was removed to expose the full face of the filter to the air stream.

The filter assembly was attached to an electric-powered vacuum pump. An inline calibrated precision rotameter was used to regulate the airflow through the filter assembly at 9.3 to 11.3 liters per minute.

The air samples were generally collected for a period of 6 to 7 hours to achieve a minimum air volume of 3200 liters for each sample. At the end of the sampling period, filters were turned upright before being disconnected from the vacuum pump and were stored in this position.

ANALYTICAL METHODS

The mixed cellulose ester membrane filters and the polycarbonate membrane filters were analyzed by TEM. The TEM analytical protocols used for the polycarbonate membrane filters are those found in WERL SOP 87-1, Revision 0.[6] Mixed cellulose ester membrane filters were prepared according to protocols found in the Asbestos Hazard Emergency Response Act in Final Rule;[7] counting rules and other analytical protocols were consistent with those used for the polycarbonate membrane filters.

ITT Research Institute performed the TEM analyses on the field samples under separate contract with EPA's Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio.

QUALITY ASSURANCE

The Quality Assurance Project Plan (QAPP) contains the complete details of the quality assurance procedures followed during this research project.[8] These procedures used for this study are summarized in the following subsections.

Sample Chain-of-Custody

Sample chain-of-custody procedures were an integral part of both sampling and analytical activities during this study. They were implemented for all air and bulk samples collected. The applied field custody procedures documented each sample from the time of its collection until its receipt by the analytical laboratory. Internal laboratory records then documented the custody of the sample through its final disposition.

Standard sample custody (traceability) procedures were used during this project. Each sample was labeled with a unique project identification number, which was recorded in the field log book along with other information specified by the QAPP.

Quality Assurance Sample Analyses

Specific quality assurance procedures for ensuring the accuracy and precision of the TEM analyses of air samples. These included the use of lot and field blanks and replicate and duplicate analyses.

Lot Blanks--

Lot blanks are filters chosen before the start of field work. These blanks are analyzed by the analytical laboratory to check for filter contamination. Two laboratories analyzed 5 percent of the total number of polycarbonate filters and 5 percent of the total number of mixed cellulose ester filters used in the 1987 field studies by TEM Level II in accordance with the Yamate procedure.[9] The polycarbonate filters were all from the same lot. The filters were considered "acceptable" for use if the average asbestos structure count per 10 grid openings was less than 3. If the average asbestos structure count for the group exceeded 3 asbestos structures per 10 grid openings, the entire lot of filters was considered contaminated. The TEM analysis of the polycarbonate filter lot blanks showed background filter contamination of 1.8 asbestos structures per 10 grid openings (or 180 asbestos structures in 1000 grid squares examined). The TEM analysis of the mixed cellulose ester filter lot blanks showed background filter contamination of 0.12 asbestos structure per 10 grid squares (or 12 abestos structures in 1000 grid openings examined). Therefore, the analysis of the lot blanks showed that the background asbestos filter contamination was within specified limits.

Field Blanks--

Field blanks are filters taken into the field and handled in the same manner as exposed air sample filters to check for contamination that might not be a result of air sampling. During setup of the air sampling pump, preloaded filter cassettes were selected as field blanks. These filters were labeled and handled in a manner similar to that used for the sample filters, but they were not attached to the sampling pump. Field blanks were collected for both polycarbonate and mixed cellulose ester filters. Table 2 presents the results for the polycarbonate, and mixed cellulose ester filter field blanks that were collected and analyzed by TEM Level II. The analysis of the

field blanks showed that asbestos filter contamination was within the guideline of an average of 3 asbestos structures per 10 grid openings.

TABLE 2. TEM LEVEL II ANALYSES OF FIELD BLANKS

Type of filter	Number of field blanks	Asbestos structures		
		Total number	Average number per 10 grid openings	Range per 10 grid openings
Polycarbonate	2	4	2	0-4
Cellulose ester	2	1	0.5	0-1
Blank guideline			3.0	

Replicate and Duplicate Analysis--

Replicate sample analysis provides a means of assessing analyst precision and refers to a second analysis of the same grid preparation by the same analyst. Three samples collected on polycarbonate membrane filters and three samples collected on mixed cellulose ester membrane filters were randomly selected for replicate analysis.

Duplicate sample analysis provides a means of assessing analytical variability introduced by the filter preparation procedure and refers to the analysis of a second grid preparation from the original filter. Three samples collected on polycarbonate membrane filters and three samples collected on mixed cellulose ester membrane filters were randomly selected for duplicate analysis.

Appendix A contains the results of replicate and duplicate sample analysis.

STATISTICAL ANALYSES METHODS

The data were grouped according to time of sampling (before and during removal activities), location of sample (outside the work area and outdoors), and filter type (mixed cellulose ester and polycarbonate). The data were then log-transferred (base e) and tested for normality by use of the Shapiro-Wilk procedure[10] to determine an appropriate statistical analytic approach for the comparisons. The transformed data suggested reasonable normality; hence, parametric statistical procedures were chosen for further analysis of the data.

Samples with a structure count of zero were assigned an estimated airborne asbestos concentration of 0 structures per cubic centimeter (s/cm^3). A concentration of 0 s/cm^3 was used in all summary statistic calculations and plots. Because the data was log-transformed for comparisons, 0 s/cm^3 concentrations were replaced by the sample's analytical sensitivity before the data transformation. (The analytical sensitivity for TEM, also referred to as the detection limit, is the estimated airborne asbestos structure concentration calculated when a single structure is counted in a sample.) This approach is recommended by the AHERA Final Rule for the clearance z-test[7].

Summary statistics (arithmetic mean, standard deviation, and coefficient of variation) were calculated for each phase of sampling (before and during removal activities) and sampling location (outside the work area and outdoors).

Statistical analyses were designed to address each of the following objectives:

Comparison of Airborne Asbestos Concentrations on 0.4-µm-Pore-Size Polycarbonate and 0.8-µm-Pore-Size Mixed Cellulose Ester Membrane Filters.

A paired sample t-test[11] was used to determine whether the mean airborne asbestos concentration found on the 0.4-µm-pore-size polycarbonate filters was significantly different from the mean asbestos concentration found on the 0.8-µm-pore-size mixed cellulose ester membrane filters. The estimated airborne asbestos concentration found on the mixed cellulose ester sample was subtracted from the corresponding estimated concentration found on the polycarbonate sample. The mean difference, which is approximately normally distributed, is then tested to see if it differs significantly from zero.

Comparison of Airborne Concentrations in the Perimeter Area Before and During the O&M Activity.

A Student's t-test[11] was used to determine whether the mean airborne concentration in the perimeter area before the O&M activity was significantly different from the mean concentration during the activity. The t-test is a standard comparison procedure of means that are normally distributed with unknown variances.

SECTION 5

RESULTS AND DISCUSSION

AIRBORNE ASBESTOS CONCENTRATION DATA

Both 0.8-μm mixed cellulose ester and 0.4-μm polycarbonate membrane filters were used to measure the airborne asbestos concentrations before and during removal of the thermal surface insulation. Summary statistics (arithmetic mean, standard deviation, and coefficient of variation) for the asbestos concentrations determined by TEM analysis of the cellulose ester and polycarbonate filters are presented in Tables 3 and 4, respectively. The results are presented by sampling phase (before and during removal) and sampling location (perimeter area and outdoors). Figures 1 and 2 present the mean asbestos concentrations for mixed cellulose ester and polycarbonate filters, respectively, and Figure 3 presents the mean concentrations for both filter types jointly. The individual cellulose ester filter results by TEM analyses are presented in Appendix B, and those for polycarbonate filters are presented in Appendix C.

The statistical evaluation of the data is presented according to the objectives stated in Section 4.

COMPARISON OF AIRBORNE ASBESTOS CONCENTRATIONS ON THE TWO FILTER TYPES

The paired sample t-test revealed no statistically significant difference in mean airborne asbestos concentrations between the two filter types ($t = 1.10$, $p = 0.2842$). The asbestos concentrations measured on 0.8-μm-pore-sized mixed cellulose ester filters are plotted against the corresponding measurements made on 0.4-μm-pore-size polycarbonate filters (Figure 4). Neither filter type consistently demonstrated a tendency to show higher or lower airborne asbestos concentrations.

Because of this lack of statistically significant different asbestos concentrations between the two filter types and because polycarbonate filter blanks indicated a marginal (but not significant) contamination problem, data from the mixed cellulose ester membrane filters were used for the remaining comparison.

TABLE 3. SUMMARY STATISTICS OF TEM ANALYSES ON MIXED CELLULOSE ESTER FILTERS

Location	Sample size	Airborne asbestos concentration, s/cm³		
		Mean	Standard deviation	Coefficient of variation
Before removal				
Outdoors	5	0.0004	0.0004	0.9170
Perimeter	10	0.0246	0.0194	0.7868
During removal				
Outdoors	0[a]	-	-	-
Perimeter	8	0.0600	0.0295	0.4919

[a] No samples were collected.

TABLE 4. SUMMARY STATISTICS OF TEM ANALYSES ON POLYCARBONATE FILTERS

Location	Sample size	Airborne asbestos concentration, s/cm³		
		Mean	Standard deviation	Coefficient of variation
Before removal				
Outdoors	5	0.0009	0.0008	0.8810
Perimeter	10	0.0329	0.0237	0.7226
During removal				
Outdoors	0[a]	-	-	-
Perimeter	9	0.0606	0.0467	0.7710

[a] No samples were collected.

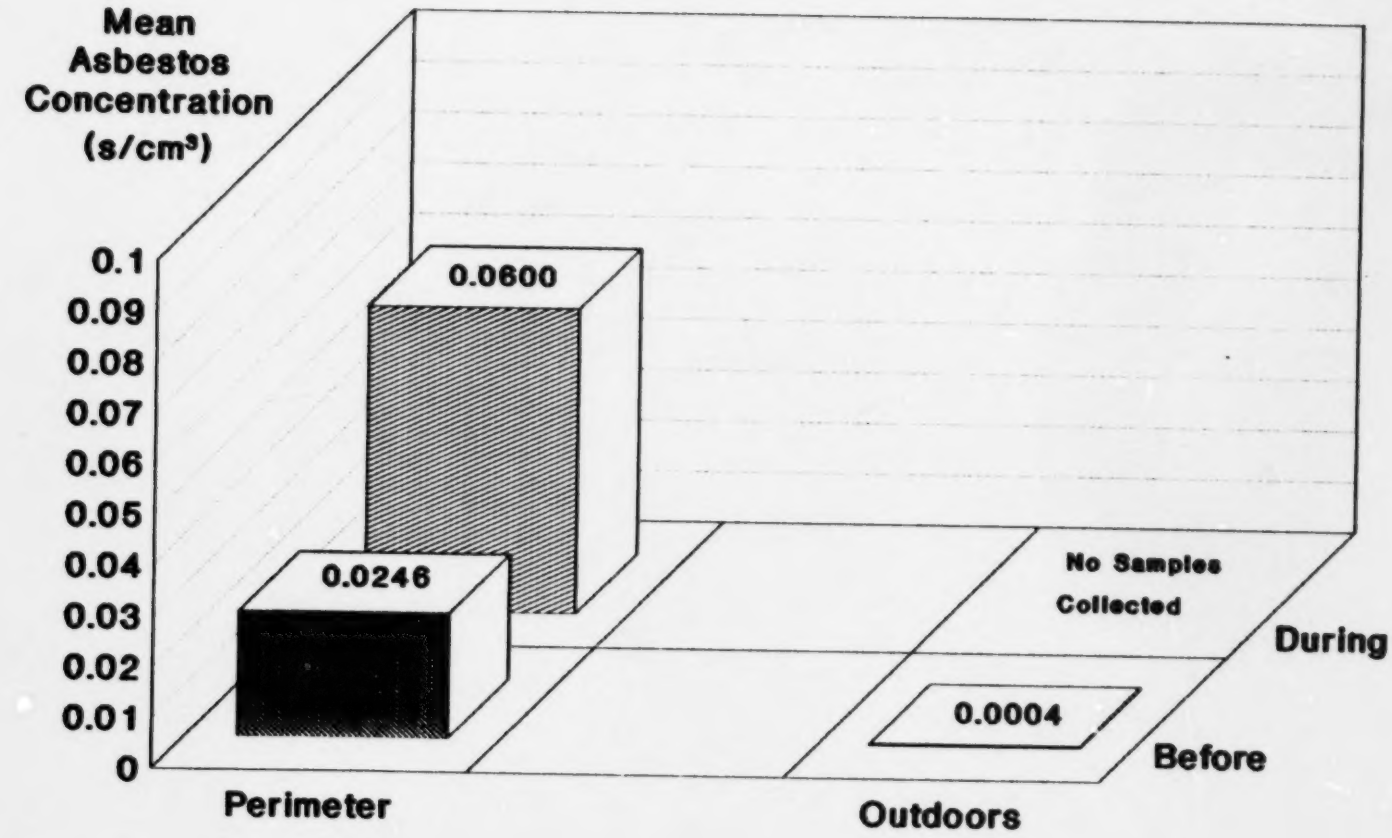

Figure 1. Mean airborne asbestos concentrations on cellulose ester filters before and during removal of thermal surface insulation.

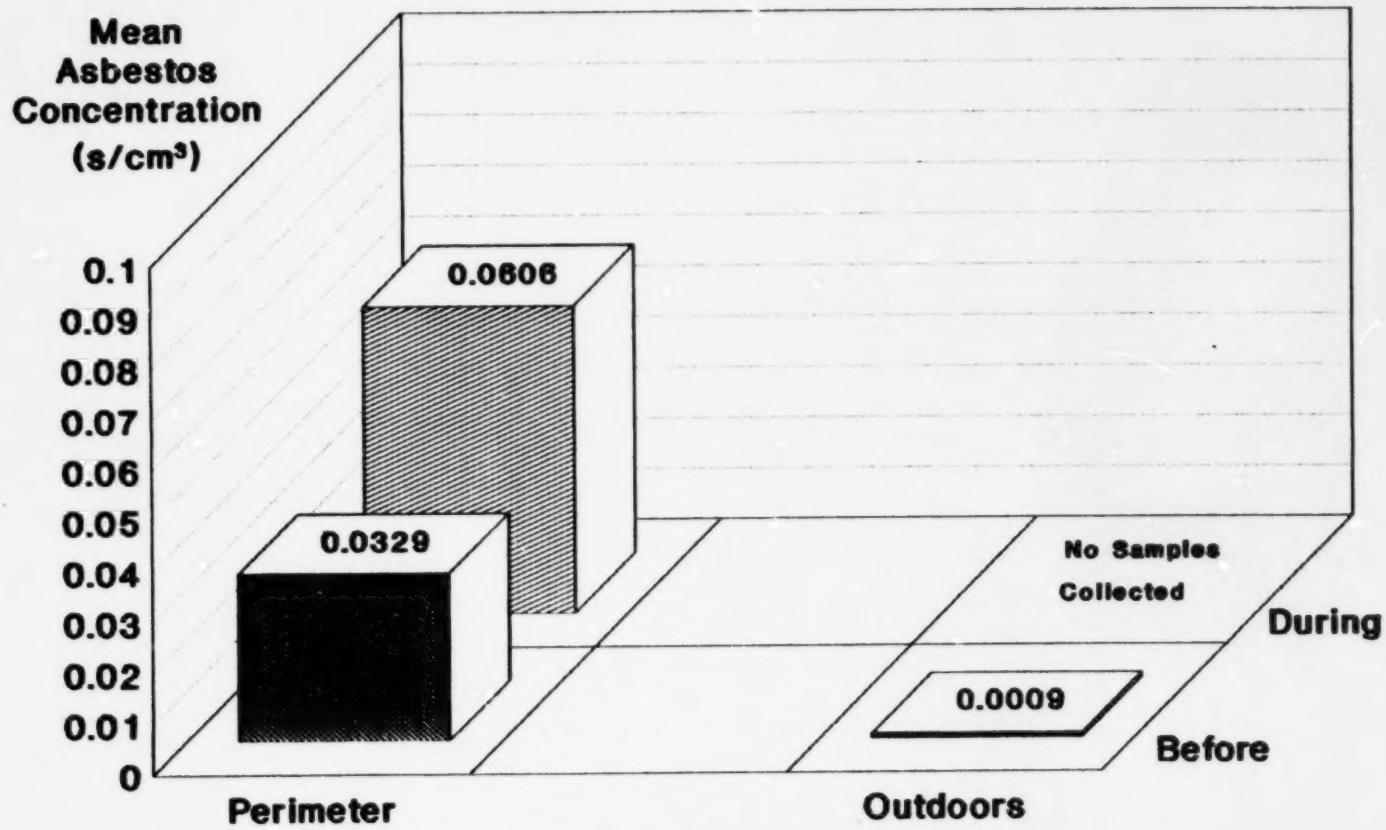

Figure 2. Mean airborne asbestos concentrations on polycarbonate filters before and during removal of thermal surface insulation.

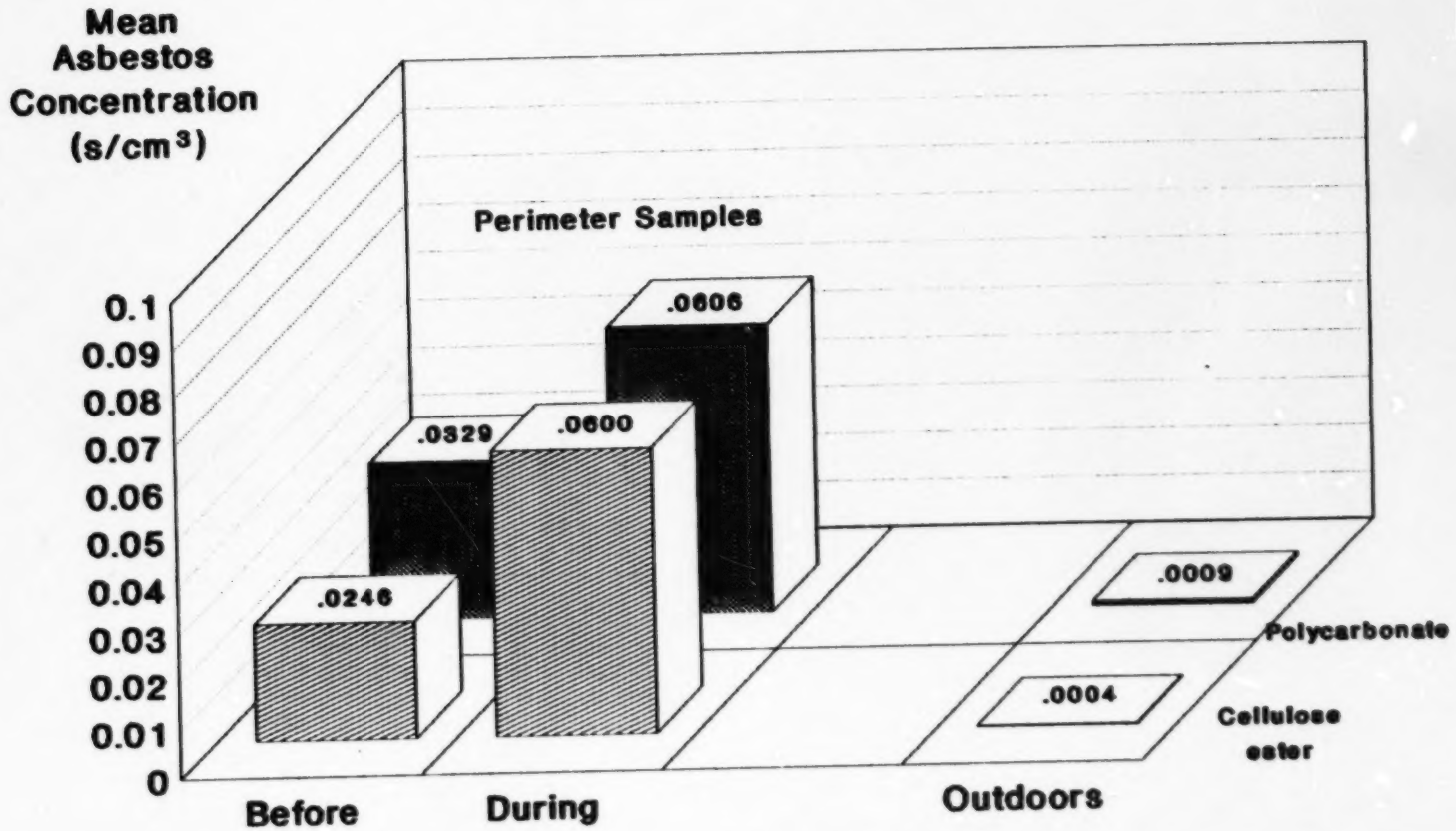

Figure 3. Mean airborne asbestos concentrations on two filter types before and during removal of thermal surface insulation.

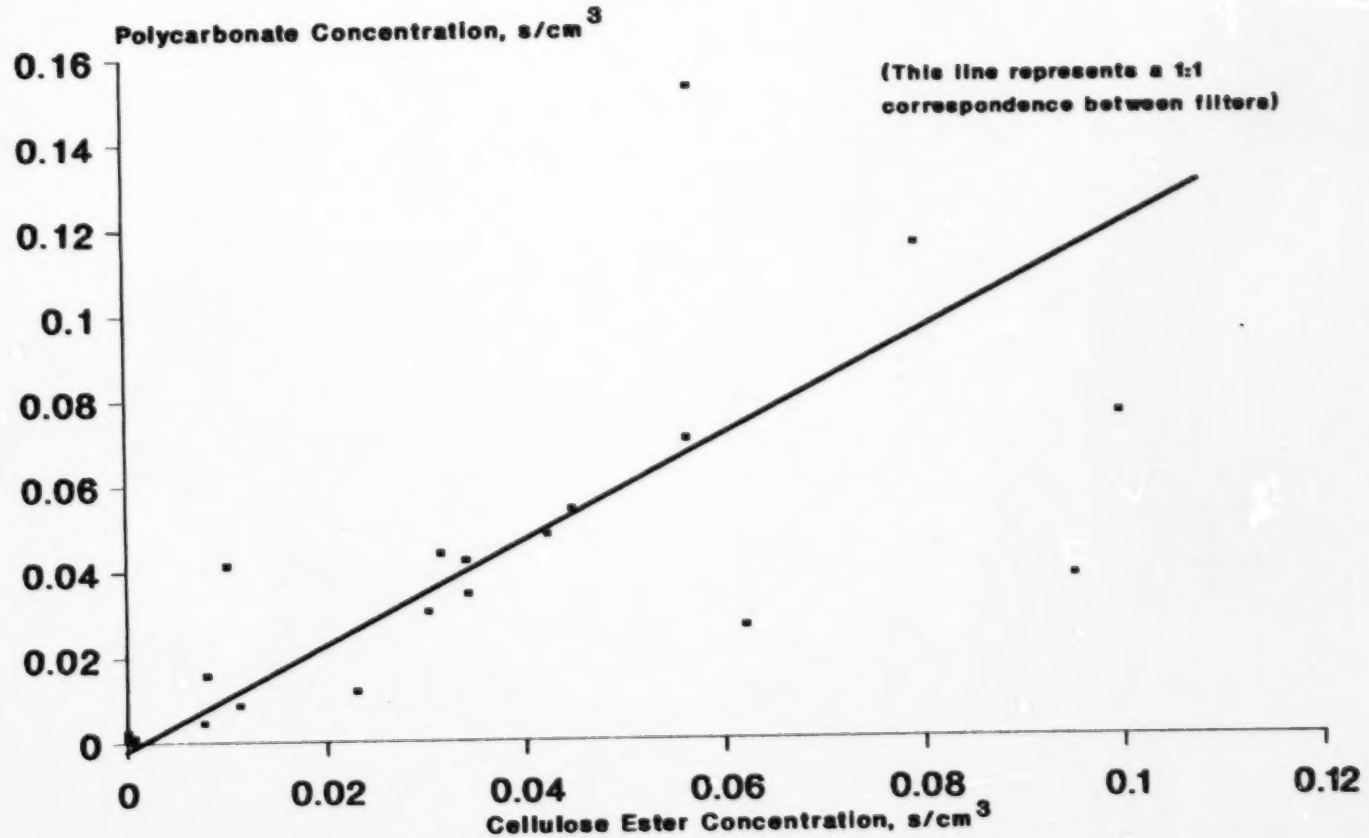

Figure 4. Relationship between airborne asbestos concentrations measured on 0.8-um-pore-size mixed cellulose ester and 0.4-um-pore-size polycarbonate membrane filters.

COMPARISON OF AIRBORNE ASBESTOS CONCENTRATIONS IN THE PERIMETER AREA BEFORE AND DURING THE O&M ACTIVITY

The mean airborne asbestos concentration (0.0600 s/cm^3) in the perimeter area during ACM removal was greater than the mean concentration (0.0246 s/cm^3) before the O&M activity for air samples collected on mixed cellulose ester filters (Figure 1). The Student's t-test showed this increase to be statistically significant ($t = 2.54$, $p = 0.0216$). The increase in airborne asbestos concentration was most likely attributable to the asbestos-containing debris that escaped the enclosure and fell to the boiler room floor.

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APPENDIX A

LABORATORY QUALITY ASSURANCE: RESULTS OF REPLICATE AND DUPLICATE SAMPLE ANALYSES

As a means of assessing the precision of the counting abilities of an individual microscopist, replicate sample analyses were performed. A replicate analysis is a second analysis of the same grids, performed by the same microscopist as in the original analysis.

A common conformance expectation for a replicate analysis is that the count from the original and replicate analyses will fall within one and one-half of the Poisson standard deviation of the average count, or as follows:

$$\mu - \frac{O+R}{2}$$

$$\mu - 1.5\sqrt{\mu} < O,\ R < \mu + 1.5\sqrt{\mu}$$

Where O is the original count, R is the replicate count, μ the average count and $\sqrt{\mu}$ is the definition of the Poisson standard deviation.

Three samples collected on polycarbonate membrane filters and three samples collected on mixed cellulose ester membrane filters were randomly selected for replicate analysis. Table A-1 summarizes the results of the original and replicate sample analyses. Two of the six samples (1392, 2343) failed to meet the conformance expectation.

As a means of assessing the reproducibility of the sample analysis, duplicate sample analyses were performed. A duplicate analysis is the analysis of a new preparation of grids made from the original filter, and performed by the same microscopist. Conformance expectations are similar to replicate analyses except the count must fall within two Poisson standard deviation of the average count.

Three samples collected on polycarbonate membrane filters and three samples collected on mixed cellulose ester membrane filters were randomly selected for duplicate analysis. Table A-2 summarizes the results of the original and duplicate analyses. All six samples met the conformance expectations.

TABLE A-1. RESULTS OF REPLICATE SAMPLE ANALYSES

Sample	Original analysis N[a]	Original analysis CONC[b]	Replicate analysis N	Replicate analysis CONC
	Polycarbonate membrane filters			
2288	64	0.0480	50	0.0315
2304	50	0.0612	41	0.0422
2343	36	0.0301	79	0.0301
	Mixed cellulose ester membrane filters			
1392	43	0.0302	98	0.0689
1414	16	0.0101	31	0.0195
1427	75	0.0566	85	0.0642

[a] Number of asbestos structures.

[b] Asbestos concentration in structures per cubic centimeter.

TABLE A-2. RESULTS OF DUPLICATE SAMPLE ANALYSES

Sample	Original analysis N[a]	Original analysis CONC[b]	Replicate analysis N	Replicate analysis CONC
	Polycarbonate membrane filters			
2264	62	0.0438	62	0.0438
2275	40	0.0377	61	0.0574
2328	43	0.0344	43	0.0344
	Mixed cellulose ester membrane filters			
1401	51	0.0342	74	0.0497
1403	67	0.0422	74	0.0466
1407	28	0.0230	41	0.0336

[a] Number of asbestos structures.

[b] Asbestos concentration in structures per cubic centimeter.

APPENDIX B

TOTAL AIRBORNE ASBESTOS STRUCTURE CONCENTRATIONS BEFORE AND DURING THE O&M ACTIVITY FOR SAMPLES COLLECTED ON 0.8-μm-PORE-SIZE MIXED CELLULOSE ESTER FILTERS ANALYZED BY TRANSMISSION ELECTRON MICROSCOPY

TABLE B-1. AIRBORNE ASBESTOS CONCENTRATIONS ON CELLULOSE ESTER FILTERS BEFORE REMOVAL OF THERMAL SURFACE INSULATION

Sample	N[a]	CONC[b]	STRMM2[c]
Outdoors			
1411	0	<0.000637	<7
1412	1	0.000633	7
1415	1	0.000687	7
1423	1	0.000734	7
1424	0	<0.000630	<7
Perimeter of work area			
1396	25	0.007639	178
1397	39	0.011196	278
1403	67	0.042235	478
1406	11	0.007959	78
1409	48	0.033954	342
1413	67	0.044688	478
1414	16	0.010061	114
1416	1	0.000741	7
1417	53	0.031480	378
1421	82	0.056279	585
Field blanks			
1425	0		<7

[a] N = Total number of asbestos particles.

[b] CONC = Asbestos structures per cubic centimeter of air sampled.

[c] STRMM2 = Asbestos structures per square millimeter.

TABLE B-2. AIRBORNE ASBESTOS CONCENTRATIONS ON CELLULOSE ESTER FILTERS DURING REMOVAL OF THERMAL SURFACE INSULATION

Sample	N	CONC	STRMM2
Perimeter of work area			
1392	43	0.030230	307
1393	87	0.062020	620
1398	102	0.094965	856
1401	51	0.034241	364
1407	28	0.022973	200
1410	101	0.099569	960
1422	98	0.079145	776
1427	75	0.056627	535
Field blank			
1400	1		7

APPENDIX C

TOTAL AIRBORNE ASBESTOS STRUCTURE CONCENTRATIONS BEFORE AND DURING THE O&M ACTIVITY FOR SAMPLES COLLECTED ON 0.4-μm-PORE-SIZE POLYCARBONATE FILTERS ANALYZED BY TRANSMISSION ELECTRON MICROSCOPY

TABLE C-1. AIRBORNE ASBESTOS CONCENTRATIONS ON POLYCARBONATE FILTERS BEFORE REMOVAL OF THERMAL SURFACE INSULATION

Sample	N[a]	CONC[b]	STRMM2[c]
Outdoors			
2272	1	0.000874	8
2303	1	0.000754	8
2326	0	<0.000817	<8
2327	1	0.000758	8
2341	3	0.002250	25
Perimeter of work area			
2263	68	0.053967	577
2264	62	0.043818	526
2265	50	0.042084	424
2271	86	0.070232	730
2273	18	0.015498	153
2288	64	0.048005	543
2301	1	0.000882	8
2302	55	0.041150	467
2339	12	0.004363	102
2342	25	0.008540	212
Field blanks			
2340	0		<8

[a] N = Total number of asbestos particles.

[b] CONC = Asbestos concentration in structures per cubic centimeter of air sampled.

[c] STRMM2 = Asbestos structures per square millimeter.

TABLE C-2. AIRBORNE ASBESTOS CONCENTRATIONS ON POLYCARBONATE FILTERS DURING REMOVAL OF THERMAL SURFACE INSULATION (s/cm^3)

Sample	N[a]	CONC[b]	STRMM2[c]
Perimeter of work area			
2262	87	0.115759	1136
2275	40	0.037666	339
2287	31	0.026296	263
2304	50	0.061172	424
2305	86	0.075660	730
2325	102	0.152728	1442
2328	43	0.034351	365
2330	12	0.011715	102
2343	36	0.030115	305
Field blanks			
2266	4		34

[a] N = Total number of asbestos particles.

[b] CONC = Asbestos concentration in structures per cubic centimeter of air sampled.

[c] STRMM2 = Asbestos structures per square millimeter.